

## ANALYSIS OF RAINFALL TREND USING MANN– KENDALL TEST AND THE SEN’S SLOPE ESTIMATOR IN UDUMALPET OF TIRUPUR DISTRICT IN TAMIL NADU

M.THENMOZHI & S.V.KOTTISWARAN

Department of Soil and Water Conservation Engineering,

Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

### ABSTRACT

*Rainfall is one of the vital climatic factors that can indicate climate change. Spatial and temporal changes of rainfall would influence runoff, soil moisture and groundwater reserves. Analysis of precipitation trends is important in studying the impacts of climate change for water resources planning and management. The present study was conducted to determine trends in the annual and seasonal total rainfall over Udumalpet region of Tamil Nadu using 33 years (1981-2013) monthly rainfall data at four rain-gauge stations. The trend analysis was done by using Mann-Kendall test and Sen’s slope estimator. The results indicated that an increasing trends varied between 43.82 mm/year at Thirumurthy nagar station and 29.37 mm/year at Nallar station, decreasing trend between 2.59 mm/year at Amaravathy nagar to 2.50 mm/year at Udumalpet. The presence of trend in annual and seasonal rainfall series determined by Mann-Kendall Z statistics and Sen’s Slope estimator reflected in the linear regression analysis.*

**KEYWORDS:** Rainfall Trend, Mann-Kendall Test, Sen’s Slope Estimator, Regression

**Received:** Feb 13, 2016; **Accepted:** Feb 24, 2016; **Published:** Mar 02, 2016; **Paper Id.:** IJASRAPR201618

### INTRODUCTION

A precipitation trend analysis, on different spatial and temporal scales, has been of great concern during the past century because of the attention given to global climate change from the scientific community, indicate a small positive global trend, even though large areas are instead characterized by negative trends (IPCC, 1996). Central Water Commission (CWC, 2005) reported that annual average precipitation received by India is about 4000 billion cubic meters (BCM). Out of that, utilized surface water and groundwater resources are approximated to be only 690 and 432 BCM respectively. Again, in the report of (CWC, 2008-09), the annual average precipitation has been approximated to be 3882.07 BCM and utilisable total surface water and total replenishable groundwater is estimated to be about 690 BCM and 433 BCM correspondingly. Therefore, it is apparent from the report that there is a reduction in the annual average rainfall over the country.

Analyzing the long term series data is used for predicting the influence of climate changes. With the growing recognition of the possibility of adverse impact of global climate change. On water resources and the background of previous researches, changes in rainfall have been studied to assess the spatial pattern of rainfall trends on seasonal and annual scales over Udumalpet region in Tamil Nadu.

## MATERIALS AND METHODS

### Study Area

The study area is located in Udumalpet, in Tamil Nadu. Geographically, it is situated at 10° 35' N latitude and 77° 15' E longitudes and it is a part of Tirupur district. The area falls under monsoon climatic region and annual rainfall is around 716.2 mm. The soil contains more of alumina and gypsum. While black soil area is utilized for agriculture. The basin's economy mostly depends on agriculture, so it is very important to analyze the rainfall trend in the basin.

### Data Collection and Analysis

Monthly rainfall data of four rain-gauge stations in the Udumalpet region for the period of 33 years (1981-2013) had been collected from the office of State Surface & Groundwater Data Centre, Public works Department, Chennai. Statistical analysis of rainfall, identification of trends using Mann-Kendal test, estimation of magnitude using Sen's slope estimator, finally trend results were compared with regression analysis.

### Rainfall Analysis

Rainfall analysis was carried out as four seasons i.e., 1) Southwest monsoon (June–September), Northeast monsoon (October–December), winter (January–February) and summer (March–May). The statistical parameters like mean, maximum, minimum, standard deviation, coefficient of variation, coefficient of skewness and kurtosis for rainfall data have been computed for studying the spatial and temporal changes in rainfall for the study area.

### Steps for Trend Analysis

The trend analysis was done in three steps. The first step is to detect the presence of increasing or decreasing trend using the nonparametric Mann-Kendall test, second step is estimation of magnitude or slope of a linear trend with the nonparametric Sen's Slope estimator, third one is to develop regression models.

### Calculation of the Mann-Kendal Test

The Mann-Kendall test statistic  $S$  is calculated using the formula that follows:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^N \text{sgn}(x_j - x_i)$$

Where  $x_j$  and  $x_i$  are the annual values in years  $j$  and  $i$ ,  $j > i$  respectively, and  $N$  is the number of data points. The value of  $\text{sgn}(x_j - x_i)$  is computed as follows:

$$\text{sgn}(x_j - x_i) = \begin{cases} 1 & \text{if } (x_j - x_i) > 0 \\ 0 & \text{if } (x_j - x_i) = 0 \\ -1 & \text{if } (x_j - x_i) < 0 \end{cases}$$

This statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples ( $N > 10$ ), the test is conducted using a normal approximation ( $Z$  statistics) with the mean and the variance as follows:

$$E[S] = 0$$

$$\text{Var}(S) = \frac{1}{18} \left[ N(N-1)(2N+5) - \sum_{p=1}^q t_p(t_p-1)(2t_p+5) \right]$$

Here  $q$  is the number of tied (zero difference between compared values) groups, and  $t_p$  is the number of data values in the  $p^{\text{th}}$  group. The values of  $S$  and  $\text{VAR}(S)$  are used to compute the test statistic  $Z$  as follows

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 \end{cases}$$

The presence of a statistically significant trend is evaluated using the  $Z$  value. A positive value of  $Z$  indicates an upward trend and its negative value a downward trend. The statistic  $Z$  has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at  $\alpha$  level of significance,  $H_0$  is rejected if the absolute value of  $Z$  is greater than  $Z_{1-\alpha/2}$ , where  $Z_{1-\alpha/2}$  is obtained from the standard normal cumulative distribution tables. The  $Z$  values were tested at 0.05 level of significance.

### Sen's Slope Estimator

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear.

$$f(t) = Qt + B$$

Where  $Q$  is the slope,  $B$  is a constant and  $t$  is time. To get the slope estimate  $Q$ , the slopes of all data value pairs is first calculated using the equation:

$$Q_i = \frac{x_j - x_k}{j - k}$$

Where  $x_j$  and  $x_k$  are data values at time  $j$  and  $k$  ( $j > k$ ) respectively. If there are  $n$  values  $x_j$  in the time series there will be as many as  $N = n(n-1)/2$  slope estimates  $Q_i$ . The Sen's estimator of slope is the median of these  $N$  values of  $Q_i$ . The  $N$  values of  $Q_i$  are ranked from the smallest to the largest and the Sen's estimator is

$$Q = Q_{\left[\frac{(N+1)}{2}\right]}, \text{ if } N \text{ is odd}$$

Or

$$Q = \frac{1}{2} \left( Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{(N+1)}{2}\right]} \right), \text{ if } N \text{ is even.}$$

To obtain an estimate of  $B$  in Equation  $f(t)$  the  $n$  values of differences  $x_i - Qt_i$  are calculated. The median of these values gives an estimate of  $B$

### Simple Linear Regression Analysis

The “simple linear regression” model is in equation form of  $Y = mX + C$ , where, Y = rainfall, X = time in years, m = slope coefficients and c = least square estimates of the intercept. The sign of the slope defines the direction of trend variable: increasing if the sign is positive and decreasing if the sign is negative. We used t test to determine the linear trends were significantly different from zero at the 5% significant level.

## RESULTS AND DISCUSSIONS

### Statistical Analysis of Rainfall

The graphical representation of annual and seasonal rainfall for four rain-gauge stations is given in Fig. 1. The statistical analysis of rainfall data is presented in Table 1. From the table it can be seen that Nallar received the highest mean annual and seasonal rainfall. The mean annual rainfall varies from 815.9 mm for Nallar to 716.22 mm for Udumalpet. Looking at the amount of rainfall in different seasons (Table 1), it is evident that all the stations receive the maximum rainfall in monsoon seasons and minimum rainfall in winter season followed by summer season.

The coefficient of variation (CV) of the annual rainfall varies between 24 % (Thirumurthy nagar) and 32 % (Nallar) indicating that there is significant variation in the total amount of rainfall between the locations.

To test whether the annual and seasonal rainfall data follow a normal distribution, the skewness and kurtosis were computed. Skewness is a measure of symmetry, or more precisely, the lack of symmetry. The data set is said to be symmetric if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Positive values for the skewness indicate that data are skewed to the right. The coefficient of skewness of monsoon seasons and annual rainfall is nearly zero indicating a near normal distribution of rainfall in the region. Rainfall during winter season is seen more skewed when compared to the rainfall during monsoon season.

Kurtosis is a measure of data peakedness or flatness relative to a normal distribution. That is, data sets with a high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution.

The correlation coefficients between rainfall and time for all four stations are presented in Table 1. The results indicated that positive correlation showed in monsoon season. In winter & summer season showed negative correlation in most of the rain-gauge stations. The highest correlation coefficient (0.57) was observed during North East monsoon whereas lowest correlation (-0.25) was observed during winter season of Amaravathy Nagar station.

### Annual Trends

Annual trends of precipitation and their magnitude (in mm/year) obtained by the Mann–Kendall test, the Sen’s slope estimator and the linear regression are given in Table 2. The annual trends found by the linear regression analyses were almost similar to the precipitation trends found by the Mann–Kendall test and the Sen’s slope estimator. Both positive and negative trends were identified by the statistical tests in annual precipitation data. However, most of the trends were non-significant at 95% confidence levels. Among the positive trends, three significant trends were observed at the 95% confidence levels. The increasing trends varied between 43.82 mm/year at Thirumurthy nagar station and 29.37 mm/year at

Nallar station significantly. The distribution of the annual precipitation trend revealed that the declining trends mostly occurred in the southeast and southwest of the study area. Adversely, no significant trend was detected in the eastern, southern and central parts of the study region.

### Seasonal Trends

The Mann–Kendall test, the Sen’s slope estimator and the linear regression were also applied to detect the seasonal trends of precipitation for 4 raingauge stations (Tables 3 and 4). The increasing trends varied between 42.21 mm/year at Nallar station and 38.78 mm/year at Thirumurthy nagar station in South West monsoon significantly. The increasing trends varied between 131.61 mm/year at Udumalpet station and 111.59 mm/year at Amaravathy nagar station in North East monsoon significantly.

### CONCLUSIONS

The annual and seasonal trends of precipitation were investigated by the Mann–Kendall test, the Sen’s slope estimator and the linear regression in this paper. For this purpose, records from 4 raingauge stations over the Udumalpet taluk for the period of 1981– 2013 were analyzed. The results indicated that an increasing trend in annual precipitation found at two raingauge stations with significant trends observed at the 95% confidence levels. The increasing trends varied between 43.82 mm/year at Thirumurthy nagar station and 29.37 mm/year at Nallar station, decreasing trend between 2.59 mm/year at Amaravathy nagar to 2.50 mm/year at Udumalpet. The negative trends can affect agriculture and water supply of the regions. The most of the trends were insignificant at the 95% and 99% confidence levels in the seasonal monsoon. The decreasing trends varied between 3.5 mm/year at Thirumurthy nagar station and 3.0 mm/year at Amaravathy nagar station in winter significantly. The increasing trends varied between 42.12 mm/year at Thirumurthy nagar station and 35.9 mm/year at Nallar station in summer significantly. The difference between the parametric (the linear regression) and non-parametric (the Mann-Kendall test and the Sen’s Slope estimator) methods on the annual and seasonal rainfall series was small. The knowledge of temporal pattern of rainfall trends analyzed in this study is a basic and important requirement for agricultural planning and management of water resources.

### REFERENCES

1. IPCC. 2007. *Climate change 2007: climate change impacts, adaptation and vulnerability*.
2. Working Group II contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report, Summary for policymakers, 23.
3. IPCC. 1996. *Climate change. In The IPCC Second Assessment Report*, Houghton JT, Meira Filho LG, Callander BA, Harris N, Kattenberg A, Maskell K (eds). Cambridge University Press: New York.
4. Jayawardene, H.K.W.I., Sonnadara, D.U.J. and Jayewardene, D.R. 2005. *Trends of Rainfall in Sri Lanka over the Last Century. Sri Lankan Journal of Physics* 6: 7-17.
5. Kendall, M.G. 1975. *Rank Correlation Methods*. Charles Griffin, London, UK.
6. Kumar, V., Jain, S. K. and Singh, Y. 2010. *Analysis of long-term rainfall trends in India. Hydrological Science Journal* 55(4): 484–496.
7. Mann, H.B. 1945. *Nonparametric tests against trend. Econometrica* 13: 245-259.

8. Obot, N. I., Chendo, M. A. C., Udo, S.O and Ewona, I. O. 2010. Evaluation of rainfall trends in Nigeria for 30 years (1978-2007). *International Journal of the Physical Science* 5(14): 2217-2222.
9. Olofintoye, O. and Adeyemo, J. 2011. The role of global warming in the reservoir storage drop at Kainji dam in Nigeria. *International Journal of the Physical Science* 6(19): 4614-4620.
10. Parta, T. and Kahya, E. 2006. Trend analysis in Turkish precipitation data. *Hydrological Process* 20: 2011–2026.
11. Salmi, T., Määttä, A., Anttila, P., Ruoho-Airola, T., Amnell, T. 2002. Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Slope Estimates-The Excel Template Application Makesens. *Finnish Meteorol. Institute Publication on Air Quality* 31: 1-35.
12. Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association* 63: 1379-1389.

## APPENDICES

**Table 1: Statistical Properties of Rain-Gauge Stationwise Annual and Seasonal Rainfall Series**

| Station/<br>Time<br>Series | Mean<br>(mm) | Maximum<br>(mm) | Minimum<br>(mm) | Standard<br>Deviatin | Coefficient<br>of Variation | Skewness | Kurtosis | Correlation<br>Coefficient |
|----------------------------|--------------|-----------------|-----------------|----------------------|-----------------------------|----------|----------|----------------------------|
| <b>Udumalpet</b>           |              |                 |                 |                      |                             |          |          |                            |
| Annual                     | 716.22       | 1321.30         | 357.00          | 210.93               | 0.29                        | 0.70     | 0.95     | 0.11                       |
| South West<br>Monsoon      | 32.00        | 83.50           | 5.00            | 18.26                | 0.57                        | 0.90     | 0.74     | 0.03                       |
| North East<br>Monsoon      | 148.79       | 325.67          | 45.00           | 63.17                | 0.42                        | 1.05     | 1.14     | 0.10                       |
| Winter                     | 13.21        | 111.20          | 0.00            | 25.74                | 1.95                        | 2.72     | 7.29     | -0.22                      |
| Summer                     | 38.86        | 118.40          | 9.00            | 22.59                | 0.58                        | 1.48     | 3.36     | 0.18                       |
| <b>Amaravathy Nagar</b>    |              |                 |                 |                      |                             |          |          |                            |
| Annual                     | 727.99       | 1216.40         | 326.70          | 218.45               | 0.30                        | 0.20     | -0.19    | 0.19                       |
| South West<br>Monsoon      | 31.48        | 83.50           | 5.00            | 18.19                | 0.58                        | 0.72     | 0.48     | -0.04                      |
| North East<br>Monsoon      | 156.35       | 325.67          | 45.00           | 68.02                | 0.44                        | 0.73     | 0.41     | 0.27                       |
| Winter                     | 12.79        | 111.20          | 0.00            | 25.82                | 2.02                        | 2.74     | 7.35     | -0.25                      |
| Summer                     | 36.69        | 97.67           | 9.00            | 18.77                | 0.51                        | 1.22     | 2.26     | 0.08                       |
| <b>Nallar</b>              |              |                 |                 |                      |                             |          |          |                            |
| Annual                     | 815.88       | 1544.70         | 341.00          | 268.31               | 0.33                        | 0.34     | 0.23     | 0.56                       |
| South West<br>Monsoon      | 54.21        | 98.65           | 4.50            | 26.62                | 0.49                        | 0.04     | -0.78    | 0.26                       |
| North East<br>Monsoon      | 150.25       | 319.70          | 16.33           | 70.57                | 0.47                        | 0.08     | -0.39    | 0.57                       |
| Winter                     | 10.47        | 95.00           | 0.00            | 20.18                | 1.93                        | 2.92     | 9.55     | -0.25                      |
| Summer                     | 42.85        | 86.00           | 0.00            | 24.46                | 0.57                        | 0.11     | -0.92    | 0.14                       |
| <b>Thirumurthy Nagar</b>   |              |                 |                 |                      |                             |          |          |                            |
| Annual                     | 747.05       | 1192.00         | 458.00          | 186.76               | 0.25                        | 0.44     | -0.42    | 0.22                       |
| South West<br>Monsoon      | 40.86        | 109.08          | 9.50            | 20.13                | 0.49                        | 1.29     | 3.28     | 0.09                       |
| North East<br>Monsoon      | 145.65       | 320.00          | 47.73           | 67.41                | 0.46                        | 1.04     | 0.89     | 0.22                       |
| Winter                     | 11.15        | 100.50          | 0.00            | 19.85                | 1.78                        | 3.24     | 12.69    | -0.17                      |
| Summer                     | 42.10        | 85.10           | 9.33            | 20.65                | 0.49                        | 0.41     | -0.50    | -0.11                      |

**Table 2: Values (Slope b of the Linear Regression Analysis, Statistics (Z of the Mann – Kendall Test and Q of the Sen's Slope Estimator) for Annual Precipitation (1981 – 2013)**

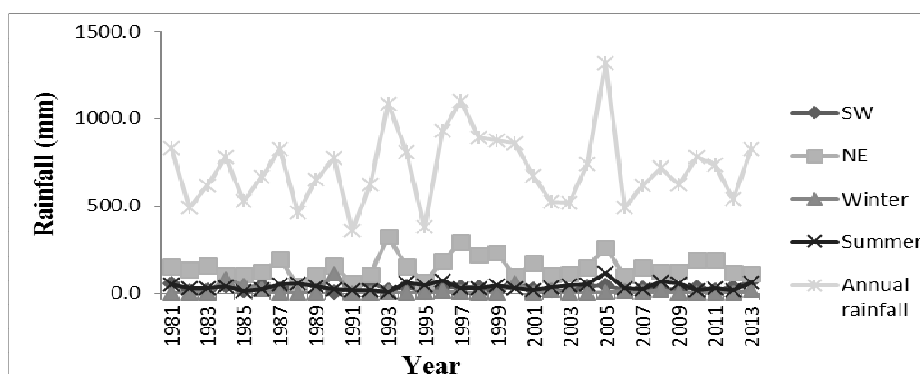
| S.No | Station           | Z                  | Q     | b (mm/year) |
|------|-------------------|--------------------|-------|-------------|
| 1    | Udumalpet         | 2.01*              | 0.50  | 2.50        |
| 2    | Amaravathy nagar  | 2.36*              | 0.52  | 2.59        |
| 3    | Nallar            | 1.71 <sup>+</sup>  | 1.63  | 29.37       |
| 4    | Thirumurthy nagar | -1.95 <sup>+</sup> | -0.74 | 43.82       |

**Table 3: Values (Slope b of the Linear Regression Analysis, Statistics (Z of the Mann – Kendall Test and Q of the Sen's Slope Estimator) for SWM and NEM**

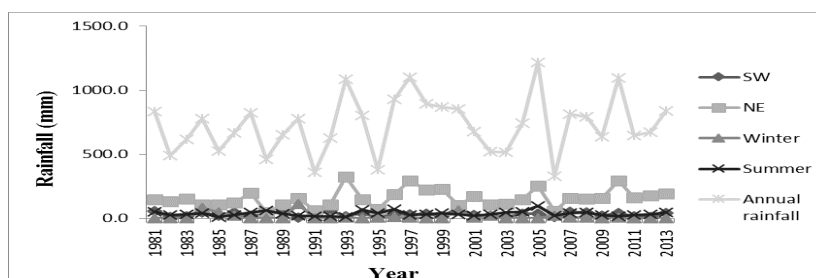
| S. No | Station           | SWM   |        |             | NEM               |      |             |
|-------|-------------------|-------|--------|-------------|-------------------|------|-------------|
|       |                   | Z     | Q      | b (mm/year) | Z                 | Q    | b (mm/year) |
| 1     | Udumalpet         | 0.17  | 0.068  | 30.57       | 0.51              | 0.39 | 131.61      |
| 2     | Amaravathy nagar  | -0.11 | -0.049 | 33.09       | 1.83 <sup>+</sup> | 2.02 | 111.59      |
| 3     | Nallar            | 1.33  | 0.75   | 42.21       | 3.11**            | 4.28 | 81.84       |
| 4     | Thirumurthy nagar | -0.17 | -0.03  | 38.78       | 1.26              | 1.57 | 107.31      |

**Table 4: Values (Slope b of the Linear Regression Analysis, Statistics (Z of the Mann – Kendall Test and Q of the Sen's Slope estimator) for winter and Summer**

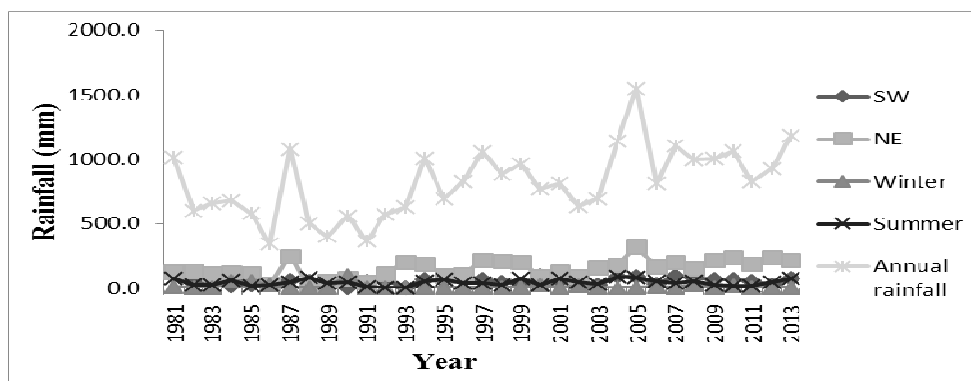
| S.No | Station           | Winter |   |             | Summer |       |             |
|------|-------------------|--------|---|-------------|--------|-------|-------------|
|      |                   | Z      | Q | b (mm/year) | Z      | Q     | b (mm/year) |
| 1    | Udumalpet         | 0.13   | 0 | 2.5         | 0.7    | 0.22  | 28.39       |
| 2    | Amaravathy nagar  | -0.09  | 0 | 3.0         | 0.5    | 0.12  | 29.09       |
| 3    | Nallar            | 0.10   | 0 | 2.0         | 0.57   | 0.34  | 35.90       |
| 4    | Thirumurthy nagar | 0.54   | 0 | 3.5         | -0.29  | -0.11 | 42.12       |



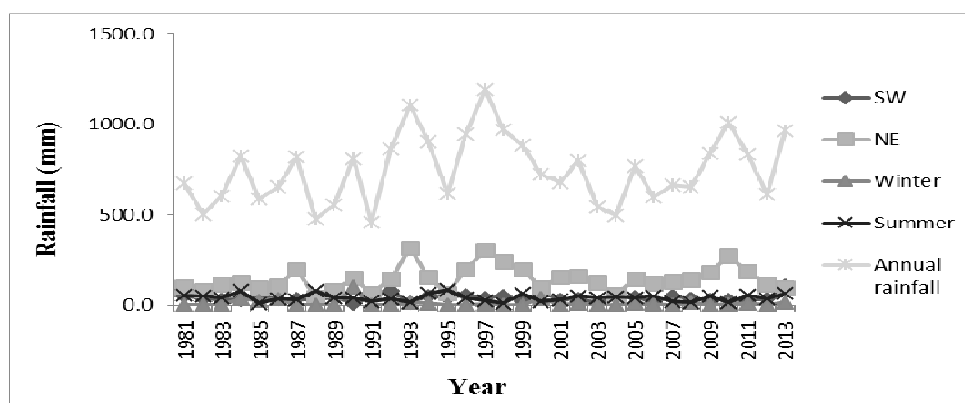
**Figure 1: Temporal Variation of Annual and Seasonal Rainfall for Udumalpet**



**Figure 2: Temporal Variation of Annual and Seasonal Rainfall for Amaravathy Nagar**



**Figure 3: Temporal Variation of Annual and Seasonal Rainfall for Nallar**



**Figure 4: Temporal Variation of Annual and Seasonal Rainfall for Thirumurthy Nagar**